

Process Maturity Progress at Motorola Cellular Systems Division

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Introduction

This year the Cellular Systems Division of Motorola submitted an application to the IEEE Computer Society for a Software Process Achievement Award. We placed second overall, with the Award going to our hosts, the Software Engineering Laboratory. In our application for the award we made public results of more than five years of effort we have been undertaking to improve our software processes.

Like many large software development organizations, we have experienced our share of customers who complain about product defects, failure to meet schedule commitments, and our inability to provide the software functionality they are demanding. By early 1990, the staff had come to recognize that the software processes in place were inadequate to meet our customer needs. Thus, in 1990 we began using the SEI Process Maturity Model (PMM) and Humphrey's *Managing the Software Process*¹ to help us define the requirements for a more mature software process. Our ultimate goals were (and still are) to improve:

- our customer's satisfaction,
- our product quality,
- our on-time delivery record, and
- our productivity.

In April of 1991, a team of SEI-trained assessors, both from SEI and from across Motorola, assessed our organization at Level 1. Then in late 1991 we were presented with a classic example of "requirements creep" when the SEI announced their first draft version Capability Maturity Model (CMM)² which was intended to replace the PMM. Careful review lead us to conclude that we had no choice but to adapt this more rigorous and detailed set of process requirements. We found to our delight that the software process architecture we developed, which was implicit in IEEE Std 1074-1991 "Standard for Developing Software Life Cycle Processes,"³ was robust enough to meet the new CMM

requirements. What needed attention were the "process specifications." These would have to be far more detailed to assure conformance to the CMM requirements. We had previously formed working groups to write process specifications for all processes, and now we began to identify the changes needed to meet the new CMM requirements. Next, we prioritized our efforts based on the CMM five-level model.

In June of 1993, after months of implementing this Software Process Improvement (SPI) Plan, we were re-assessed formally (using the PMM) at Level 2. More importantly, as more of our processes have begun to conform to the CMM requirements, we have begun to demonstrate significant measurable improvement in delivered product quality and on-time delivery, delivering more functionality to a more-satisfied customer, as accompanying data will support. Our data gathering activities have lagged behind other process changes, and key process measures were not routinely made before 1992, but we think that it is important to keep in mind that the data presented covering the last six quarters effectively represent results of process improvements underway since early 1991.

To support the Nomination of the SPI team at CSD a set of representative data was prepared. We presented data from a single product software development group representing about three hundred developers in our division. Since the submission of this application we have continued our efforts, and new data continues to demonstrate the benefits. We will review all of the data we have available to us at this time, which represents the time frame from the first quarter of 1992 to the end of the second quarter of 1994. Data from all projects completed by this product group and released to customers in that time frame are included. Six charts will be presented.

Figure 1

This figure shows our progress made in achieving

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compliance with the requirements of the six Level 2 Key Process Areas (KPA) named in the SEI CMM, Requirements Management (RM), Project Planning (PP), Project Tracking (PT), Subcontractor Management (SM), Quality Assurance (QA), and Configuration Management (CM).

An internally-developed procedure is used to assess compliance, and each development group conducts quarterly internal self-assessments.⁴ The assessment procedure focuses on key practices described in the CMM, and compliance is contingent upon evidence of the presence of each key practice. The "percent compliance" described in this Figure is therefore the mean percent compliance of all of the key practices in each KPA which are evident to the assessment team. Outside team members from other development organizations and from the software quality assurance organization participate in these assessments to assure more-uniform and rigorous scoring.

The first round of these assessments was held in the third quarter of 1992, and the results of that assessment are compared to the current scores. The entire development organization was assessed at Level 2 using the PMM in June of 1993, but this development group had not yet achieved complete compliance with all of the requirements of the CMM at that time. However, since then significant progress has been made, and full implementation of all the key practices described in each KPA is now evident.

Figure 2

With the completion of our formal Self-assessment in June 1993, when we were rated at Level 2, the entire organization has moved forward with an initial assessment of our status with respect to the key practices found in Level 3 KPAs using our self-assessment procedure. The initial scores of this development group are presented in this chart. The initial conclusion one might draw from this chart is that the group is far from compliant with the requirements for Level 3. In view of our initial scores on the Level 2 Key Process Areas, however, we are confident that the group can be expected to make rapid progress toward compliance. Combined

with the information presented in Figure 1, we can see that the group is in full compliance with Level 2 KPAs, and working on improvements on the Level 3 KPAs.

Figure 3

A customer survey is conducted regularly by an independent market research firm using a "Motorola Confidential Proprietary" survey questionnaire. In constructing this survey questionnaire "Key Drivers" have been identified which represent our effort to measure what our customers think is important. Each satisfaction survey measures our performance on these Key Drivers. Figure 3 compares our percent improvement in this product group for the Key Drivers which are concerned with software, in comparison to our performance in 1991. Since the survey contents and results are confidential, we have represented our progress by means of an index, with year-end 1991 results being "1," and year-end 1992 and 1993, and year-to-date 1994 being shown relative to that index quantity.

Figure 4

To explain Figure 4, some specific definitions are required.

Customer Found Defects are those post-release defects which are found by the customer. This does not include post-release defects found by Motorola internally, or defects of which customers have been notified before these customers find them.

Each customer found defect is recorded based upon the release in which it is found. A "window of opportunity" to find defects exists for each successive release. For a particular release, the first opportunity to find and report defects occurs at the time the first customer installs it. Defects in that release can be found by customers up to the time the last customer using that release retires it. Most releases are in use about 12 to 18 months. When a release is made in a particular quarter, and defects are reported against that release, the number of Customer Found Defects for all releases in that quarter is incremented. Over time, if additional defects against that release are reported, the quarterly total of defects for releases in that quarter is incremented. As releases are retired, since defects

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can no longer be reported further against them, the total defect count becomes fixed. Our experience, like most software developers, is that most Customer Found Defects ever found are reported in the first quarter of use.

Delta KAELOC is the size of the added, deleted, and modified source code expressed in thousands of Assembly-Equivalent Lines of Code. This number is calculated based on a factor specific to each programming language used using the table provided by Capers Jones of SPR, Inc.

Total KAELOC is the total size of the released software expressed in thousands of Assembly-Equivalent Lines of Code. This number is calculated based on a factor specific to each programming language used.

Figure 4 demonstrates that in this time period the number of customer found defects has continued to decline, and that our most-recent releases are approaching 6 sigma quality.

Figure 5

Delay in delivery of promised software releases is a key contributor to customer dissatisfaction. In all of our product groups, release dates are forecast at the time of "project initiation" when the release project plan is approved and development begins. Figure 5 records for each release in a quarter how long after the forecasted release date the actual release occurred. Coincidentally, there has been one release per quarter for this product for the last two years.

Figure 5 shows a step-function improvement occurred in on-time deliveries between the releases in the second and third quarters of 1992. This came about primarily through better management controls in project planning and project tracking. Demonstrating that we are still a Level 2 organization, one release was delayed significantly in the second quarter of 1993 because of a delay in delivery of a vendor's code, and because some key staff members were temporarily reassigned to another project. In the fourth quarter of 1993 another release was delayed because of extended negotiations with a key customer on feature content for the release. This experience clearly highlights why both subcontractor management, project tracking, and requirements are key contributors to

customer satisfaction. A note of explanation about the seeming lack of data for the first quarter of 1993. In fact, this release was exactly on time, thus the delay was zero months.

Figure 6

More and more functionality is being demanded by our customers, and with each new release we place more functionality into the customer's hands. Figure 6 demonstrates the extent to which the amount of new code (Delta KAELOC, as defined in the note to Figure 4) is growing at each release. In data not presented here we have measured that our productivity in terms of the number of lines of code produced by each software engineer has more than doubled in this time. Thus, while we have added staff, the staff has continued to increase the amount of code being delivered. The decline in the total number of new lines of code evident in 1994 results from the fact that this product development group is in the midst of a major product upgrade this year and only small, point releases have been made this year while most work continues to focus on the planned major upgrade to occur in the first quarter of 1995.

Returning to a topic mentioned in the note to Figure 4 we want to reiterate that even though we have increased the number of lines of code delivered with each new release by seven-fold, we are still seeing a significant decline in the number of customer-found defects in these releases. Stated simply, we are releasing more functionality to our customers, with higher productivity, and with fewer defects.

Summary

We believe that the key success elements are related to our recognition that Software Process Improvement (SPI) can and should be organized, planned, managed, and measured as if it were a project to develop a new process, analogous to a software product. In summary, we believe that our process improvements have come as the result of these key elements:

- use of a rigorous, detailed requirements set (CMM),
- use of a robust, yet flexible architecture (IEEE 1074),

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- use of a SPI project, resourced and managed like other work, to produce the specifications and implement them, and
- development of both internal and external goals, with metrics to support them.

We have achieved significant, measurable results as a result of these efforts, and we want to share these findings with a broad industry audience. Our efforts may be viewed as unique in the sense that our business is entirely commercial and we have no customer pressure to adopt any particular paradigm for improvement, yet we selected the SEI Process Maturity Model and have successfully used the requirements of this Model to drive software process improvements. In a sense, we have validated this Model for change, and used it to substantially change our development processes and the customer's view of our product.

References

1. Humphrey, Watts S. *Managing the Software Process*, Addison-Wesley Publishing Company, Reading, MA, 1989.
2. Paulk, Mark C., et al. *Capability Maturity Model for Software, Version 1.1*, Software Engineering Institute, Carnegie Mellon University, Pittsburgh, PA, February, 1993.
3. IEEE Std. 1074-1991 *IEEE Standard for Developing Software Life Cycle Processes*, Approved September, 1991. The Institute of Electrical and Electronics Engineers, Inc.
4. Daskalantonakis, Michael "Achieving Higher SEI Levels" in *IEEE Software*, July, 1994, p. 17.



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Cellular Infrastructure Group

Presentation to: Nineteenth Annual Software Engineering Workshop

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November 30, 1994**



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Topics

- **Introduction**
- **Our Experiences**
- **Results**
- **Summary**
- **Lessons Learned**

*19th SEW
November 30, 1994*

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Congratulations to the SEL!

- Winner of the IEEE Computer Society Software Process Achievement Award for 1994
- Motorola's Cellular Systems Division (CSD) was "First Runner Up"
- We are the "Avis" of Process Achievement this year, and "trying harder."

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Motorola Cellular Systems Division (CSD)

- Approximately 1,000 in the R & D Division
- Four locations:
 - Arlington Heights, IL, USA
 - Cork, Ireland
 - Tel Aviv, Israel
 - Ft. Worth, TX (the fourth country)
- Data presented here is for the EMX 2500 Switch Software Development Group (~300 staff)

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CSD Key Events

- Motorola has a corporate software engineering goal to achieve SEI Level 3 by YE'95
- CSD had first SEI Self-assessment in Nov. '90
- Level 1 (are you surprised?)
- Second Self-assessment, June '93
- Level 2 (pew! Made it)
- Third Self-assessment scheduled *next week*

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CSD Key Strategy Decisions

1. Use SEI 5-level Model for "Requirements"
2. Use IEEE 1074 for the "Design"
3. Implement a "Process Improvement" Project

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Summary of Results

- Progressive improvements in "Process Maturity"
- Continuous improvements in quality, productivity, on-time delivery, and customer satisfaction
- "Quantum leap" in the quality of work life

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FIGURE 1 - SEI CMM Level 2 - Key Process Area Compliance (Self-Scored)

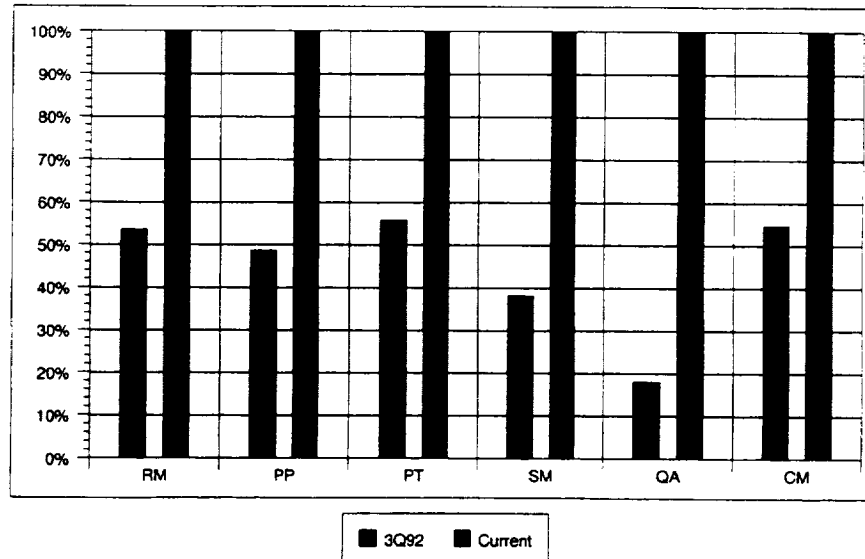


FIGURE 2 - SEI CMM Level 3 - Key Process Area Compliance (Self-Scored)

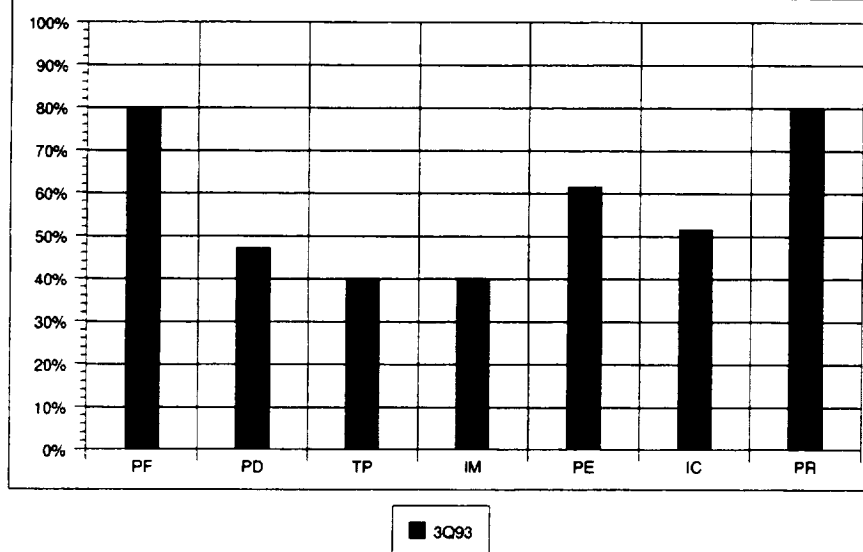
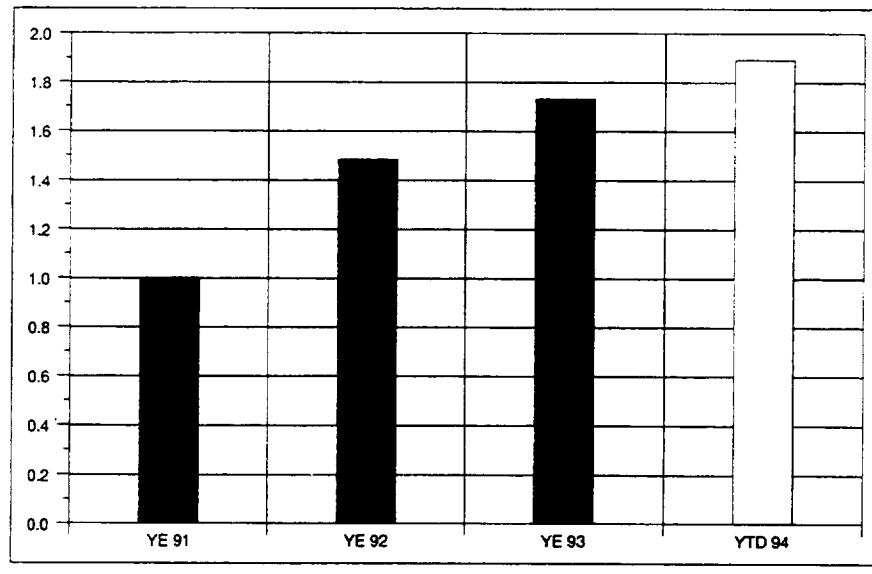
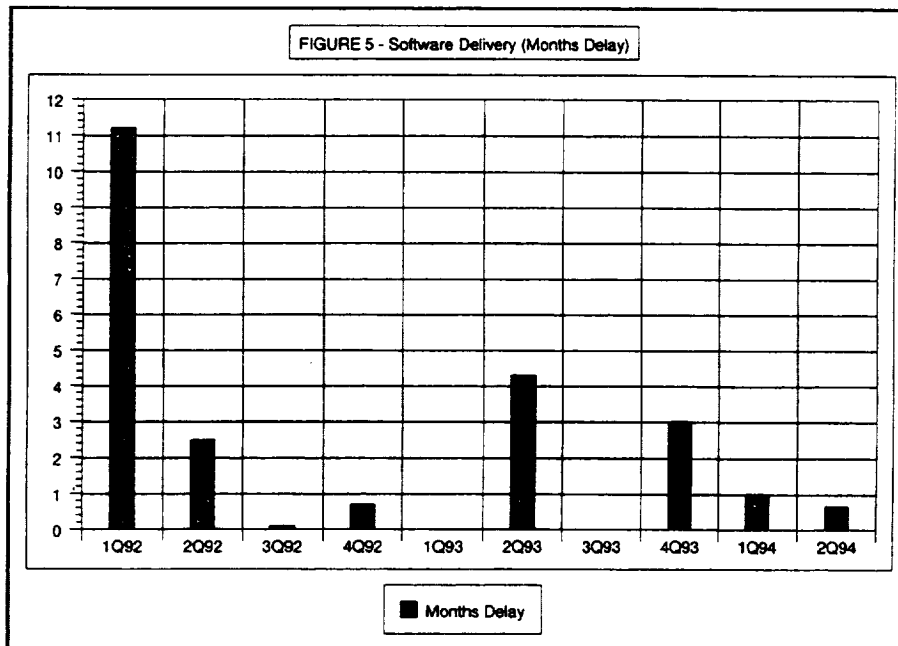
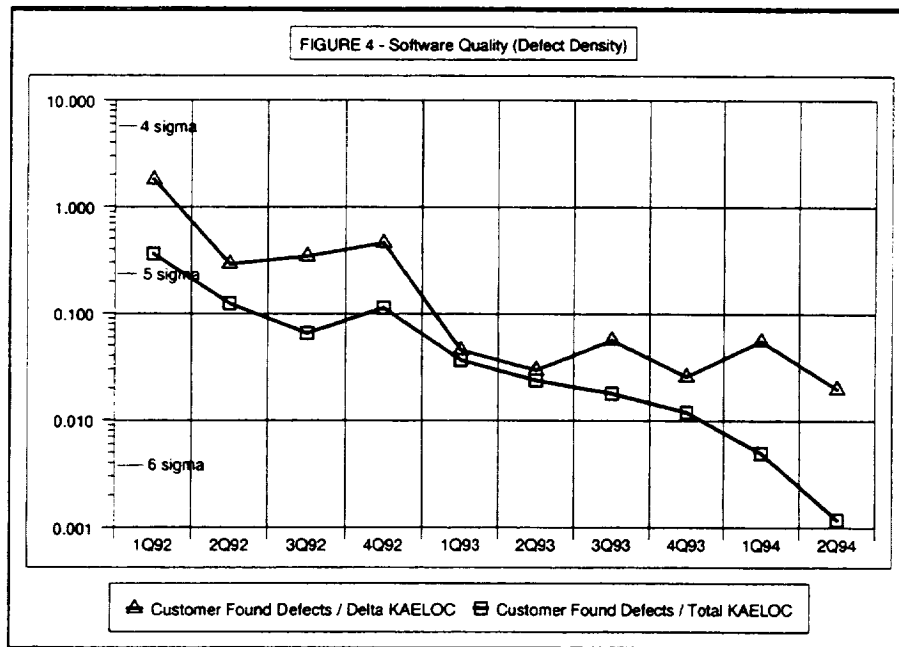
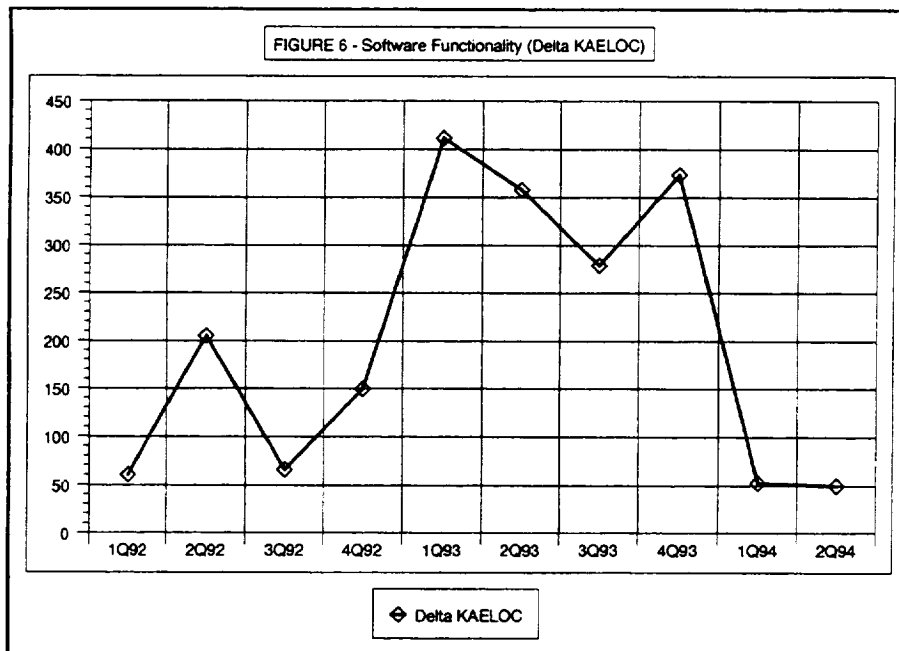


FIGURE 3 - Customer Satisfaction (Software)







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Lessons Learned

- “Plan your work”--in this case Process Improvement
- “Work your plan”--in this case the Process Improvement Project Plan
- This Project has:
 - Requirements Specifications
 - Design Architecture
 - Implementation Phases
 - Verification and & Validation Phases

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